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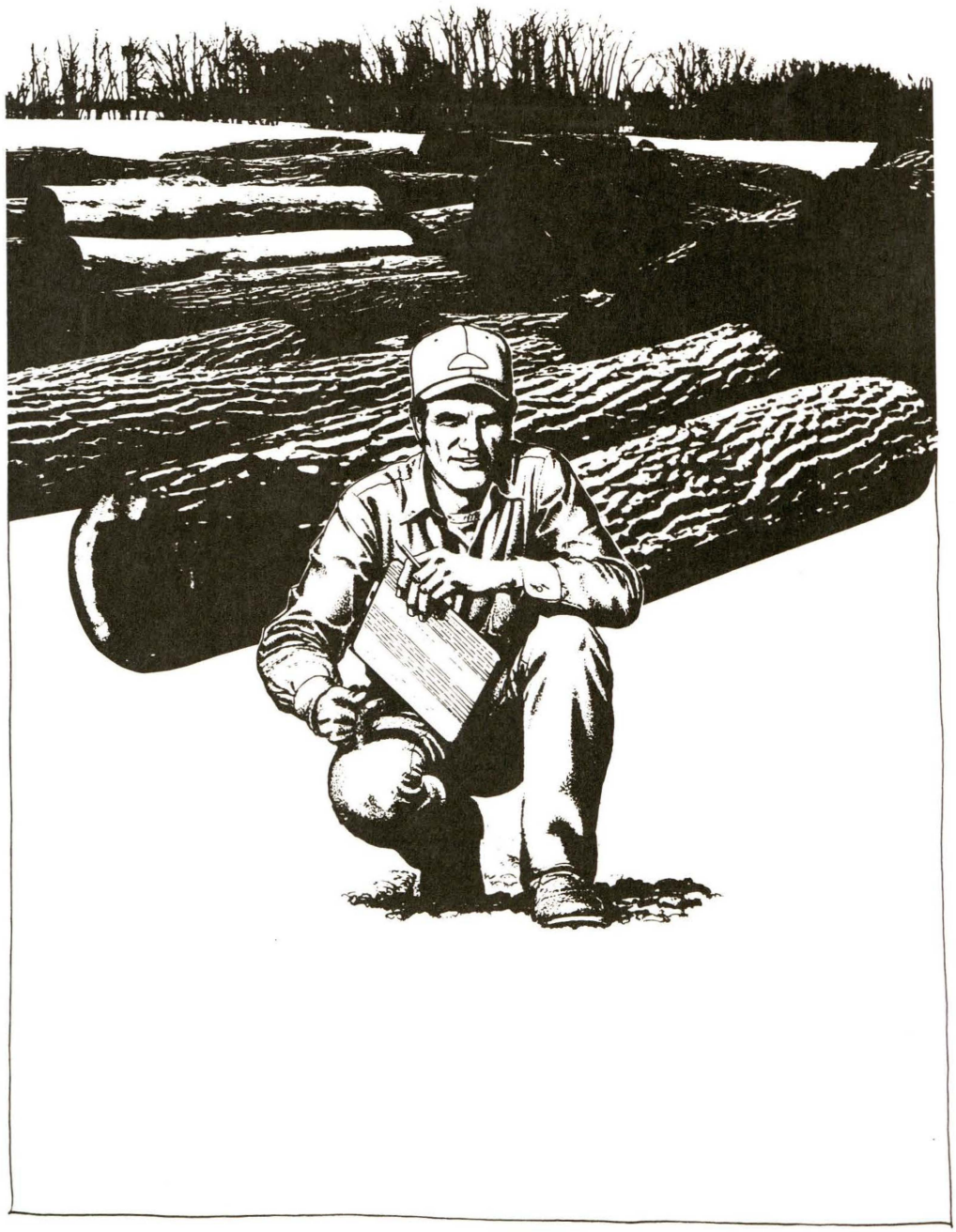
Central States Forest Management Guides as Applied in STEMS

Nancy R. Walters



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Describes a management prescription system for Central States cover types developed for use in the Central States Stand and Tree Evaluation and Modeling System (STEMS). It includes one management guide for each of the six major covertypes in the region. Each guide consists of a decision key that prescribes management, based on stand characteristics and a set of marking rules that carries out the prescription. This management component can be used within STEMS or apart from it as a guide to making silvicultural decisions in the Central States.

KEY WORDS: Silvicultural guidelines, computer model, growth and yield, timber management.

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CENTRAL STATES FOREST MANAGEMENT GUIDES AS APPLIED IN STEMS

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Growth and yield projection models have become one of the tools commonly used by forest managers and planners in making decisions about the forest resource. Growth simulators aid in resource assessment by providing a means to update forest inventories and estimate future yields. Growth models become particularly useful when, in addition to projecting the growth of stands, they can simulate management (tree cutting) and describe how those management actions will affect future stand development.

The Stand and Tree Evaluation and Modeling System (STEMS) is an example of such a growth model (Miner and Walters 1984). Scientists at the North Central Forest Experiment Station developed STEMS for use by forest managers and planners wanting to evaluate many stands simultaneously, such as in regional analysis. It operates on a mainframe computer and is being used by forest industries, States, and the USDA Forest Service Forest Inventory and Analysis group, among others. Two variants are available: Lake States STEMS, intended for use in Minnesota, Wisconsin, and Michigan; and Central States STEMS, for use in Missouri, Illinois, and Indiana.

The management component in STEMS was designed with the understanding that users would be evaluating many forest stands at one time and that the stands would represent a wide variety of forest types and conditions. To be of value in a system such as STEMS, the management component needed to be able to prescribe and apply management actions as well as be flexible enough to allow the user to alter those prescriptions. To achieve these goals, a set of computerized management guides was developed that has the capacity to automatically assess a stand's condition and apply an appropriate management prescription. The user can easily modify these guides, tailoring the management prescription to fit specific conditions or objectives.

This paper describes the management component developed for use in the **Central States** variant of STEMS. Similar guides have been developed for Lake States STEMS (Brand 1981).

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MANAGEMENT GUIDES WITHIN THE STEMS FRAMEWORK

The management component of Central States STEMS includes six management guides, one for each major covertype of the Central States region:

Eastern redcedar	Elm-ash-cottonwood
Shortleaf pine	Pin oak
Oak-hickory	Tolerant hardwoods

Each computerized guide is a synthesis of existing information on managing the particular forest type. Published information widely used by forest managers as well as unpublished information from foresters who are experienced in managing Central States forests provided the basis for these guides. A complete list of the sources used to develop the guidelines is included in the Literature Cited.

The guidelines prescribe treatments for individual stands using stand information that is provided as input to STEMS. This information is in the form of a tree list that is altered as trees grow, die, and are cut. For each tree on a sample plot, the STEMS tree list includes the species, diameters, crown ratio and tree quality codes as well as stand age and site index (Miner and Walters 1984). These data provide the only information required by STEMS for projecting tree growth and mortality, deciding on a management prescription, and selecting trees to cut.

Using the information supplied in the tree list, STEMS determines the covertype of the stand and

then selects the appropriate management guide (Belcher 1981). The management guide for each covertype consists of a decision key and a set of marking rules. The *decision key* (Appendix A) is an algorithm that determines the stand characteristics and prescribes appropriate management. The *marking rules* (Appendix B) carry out the silvicultural prescription, assigning the sequence in which trees will be cut.

THE DECISION KEY

The decision key is like a map of roads branching in different directions, each leading to different silvicultural prescriptions (fig. 1). At each intersection or decision point, true/false questions about characteristics of the stand are answered based on the stand and tree information. True statements are followed until enough stand information is accumulated to make a silvicultural prescription.

Depending on the covertype being considered, the "map", or decision key, may be very complex or relatively simple. The silvicultural prescriptions are based on a variety of stand characteristics, depending on the covertype being evaluated. In some covertypes it is necessary to know stand density to make management recommendations. In others, treatments are prescribed based on the age and/or site index of the stand. Table 1 describes that array of stand characteristics used at the decision points of the keys. These characteristics provide the basis for making the prescription, and some or all of them, in varying combinations, are used in each of the six keys.

Obviously, forest management decisions in the real world are based on many other factors besides those

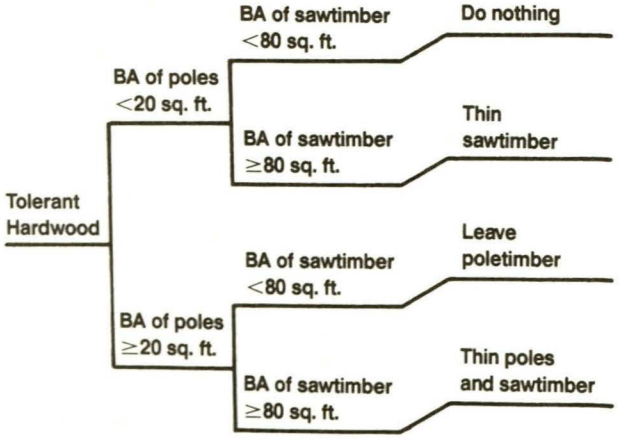

Tolerant Hardwood
BA of poles <20 sq. ft.
BA of poles ≥20 sq. ft.
BA of sawtimber <80 sq. ft.
BA of sawtimber ≥80 sq. ft.
BA of sawtimber <80 sq. ft.
BA of sawtimber ≥80 sq. ft.
Do nothing
Thin sawtimber
Leave poletimber
Thin poles and sawtimber

Figure 1.—*Simplified tolerant hardwood decision key (BA = Basal Area).*

Table 1.—*Description of terms used in decision keys*

Symbol	Units	Description
Age	Years	Stand Age
BA	sq.ft./acre	Basal area of all live trees on the stand (acceptable and unacceptable growing stock)
BA/AGS	sq.ft./acre	Basal area of acceptable growing-stock trees
BLINE	sq.ft./acre	Basal area at the minimum stocking level (see decision keys for calculation)
BASAW	sq.ft./acre	Basal area of all live sawtimber-size trees
BAPOLE	sq.ft./acre	Basal area of all live poletimber-size trees
BASAP	sq.ft./acre	Basal area of all live saplings
$\overline{DBH}$	inches	Average diameter at breast height of live trees on the stand
NT	trees/acre	Number of live trees per acre on the stand
QMDBH	inches	D.b.h. of tree of average basal area: square root of (BA/0.005454 • NT)
SI	feet	Stand site index (50 year basis)
Rough & Rotten	number of trees	Unacceptable growing stock trees
$<$		as in a $<$ b: a is less than b
$\leq$		as in a $\leq$ b: a is less than or equal to b
$>$		as in a $>$ b: a is greater than b
$\geq$		as in a $\geq$ b: a is greater than or equal to b

listed in table 1. The stand's health, its location, insect and disease problems, and the current market conditions are just a few of the additional factors considered in determining silvicultural prescriptions. Because, in modeling, so many of these dynamic characteristics cannot easily be considered, a few initial assumptions are made. One of the basic assumptions is that STEMS does not account for shrubs or intertree spacing so it therefore does not reflect the effects they may have on tree growth. In addition to this basic assumption, special assumptions are made for each covertype (see Decision Keys in Appendix A).

Figure 2 illustrates the decision key for the tolerant hardwood covertype. The circled numbers pertain to marking rules that will be discussed later. This management guide operates on the above basic assumption as well as the assumption that all-aged stands will be maintained or developed and that the management objective is timber.

The guide for this covertype bases its management prescriptions on the density distribution in the stand. At the first decision point the amount of basal area in poletimber (BAPOLE) is assessed. At the next decision point basal area in sawtimber-size trees (BASAW) is determined. At each of these decision points STEMS compares the stand's characteristics calculated from the tree list to the decision values built into the management guides. Those values

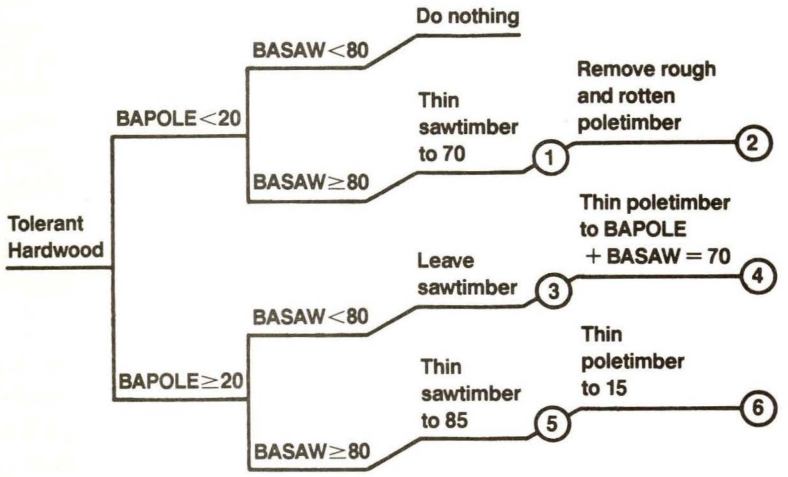


Figure 2.—*Tolerant hardwood decision key.*

associated with the stand characteristics at each decision point are called "critical values". In this decision key the critical value for BAPOLE is 20 square feet. Stands with less than 20 square feet in poletimber (BAPOLE < 20) follow the top branch. Those stands with 20 square feet or more in poletimber (BAPOLE ≥ 20) follow the lower branch. Similarly, the critical value for BASAW in this key is 80 square feet. The critical value for BASAW happens to be the same for each of the two sets of branches, but they may be different for each set of branches in other keys. Default critical values, based on published management guidelines, are established for each decision key and are used unless changed by the user.

To demonstrate how a decision key is used to determine a silvicultural prescription, assume we have a sugar maple-beech stand (ie., tolerant hardwood covertype) with 100 square feet total basal area including: *18 square feet in poletimber*, and *82 square feet in sawtimber* (fig. 3).

To determine the prescription for this stand, the basal area in poletimber (BAPOLE) of 18 square feet is compared to 20 square feet, the critical value at the first decision point. Because the stand has less than 20 square feet in poletimber, the upper branch is followed. At the next decision point, because the basal area in sawtimber (BASAW) of 82 square feet is more than the critical value of 80 square feet, the

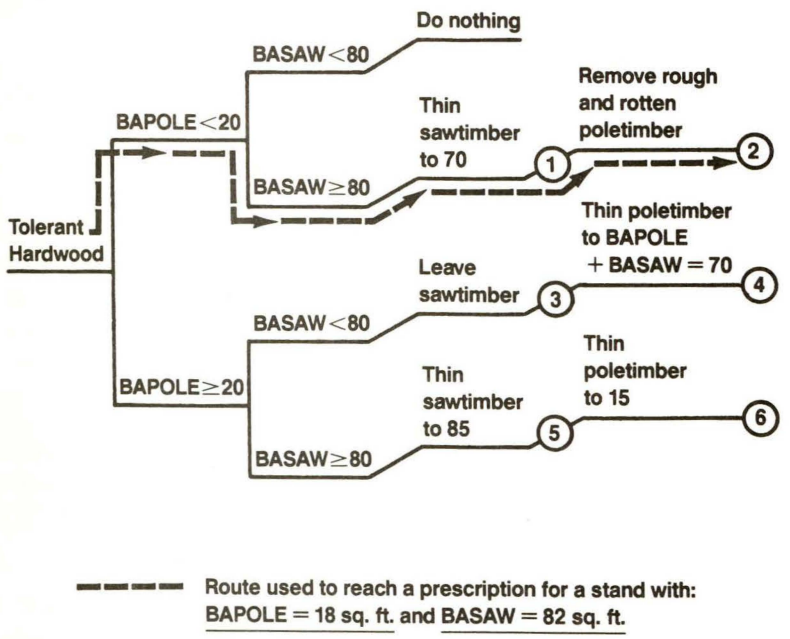


Figure 3.—*Example of how a decision key is used.*

lower branch is taken. That lower branch leads to a prescription that thins the sawtimber size class to 70 square feet and removes rough and rotten poletimber.

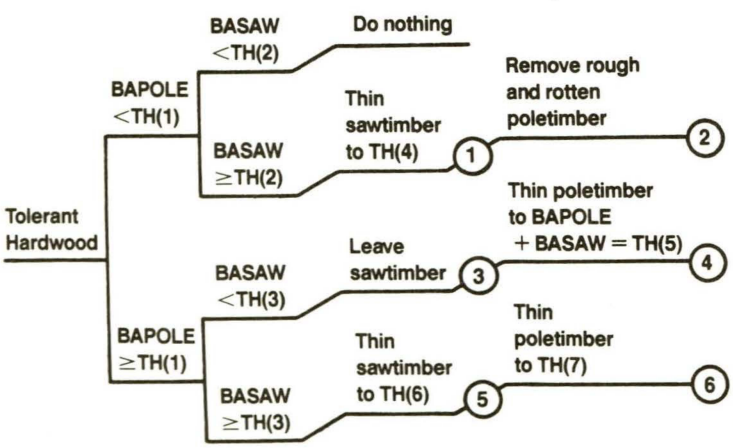
Although the silvicultural prescriptions made by these management guides are usually reasonable, for many different reasons they sometimes are not. Perhaps the assumptions don't apply in the user's situation or the market conditions make the prescribed management impractical. In these situations, users can do one of two things. One option is to choose one of the other available guides rather than the one chosen by STEMS. For instance, the oak-hickory guide provides guidelines for even-aged management and may not be useful to those having uneven-aged managment goals for upland hardwood stands. In this case the user could chose to use the tolerant hardwood guide, which provides guidelines for uneven-aged management, and override the assigned even-aged management guide.

The other option is to modify the key so that a different outcome is produced. This flexibility is provided by allowing the user to change the critical values at each decision point. The stand characteristic itself (e.g., BAPOLE, BASAW), cannot be changed, nor can the framework be altered; only the value at each intersection is variable.

To provide this flexibility, the critical values that may be changed are designated by symbols. In the tolerant hardwood key, the critical values are denoted as TH(1), TH(2)...TH(7) (fig. 4). TH(8) allows the user to set the lower limit for the sawtimber size class (see fig. 4, assumption 3). The values assigned to each symbol are stored in an auxillary data file and are used in STEMS unless changed by the user. Using the default values as printed in figure 4, this generalized key would produce the same prescription for any given stand as would the specific key in figure 3.

As an example of how these critical values are used to provide flexibility in management, let's use the same sugar maple-beech stand and add an assumption. Assume market conditions are such that it is not economically feasible to enter the stand as often as would be silviculturally advisable (fig. 5). Let's say we'd want to have 90 square feet of sawtimber present before entering stands with a small proportion of poletimber.

By changing TH(2) from 80 to 90 square feet, the prescription will be to "do nothing" for any stand with less than 20 square feet in poletimber and less than 90 square feet in sawtimber. Because our example stand has 18 square feet of poletimber and 83 square feet in sawtimber, we follow the path to the "do



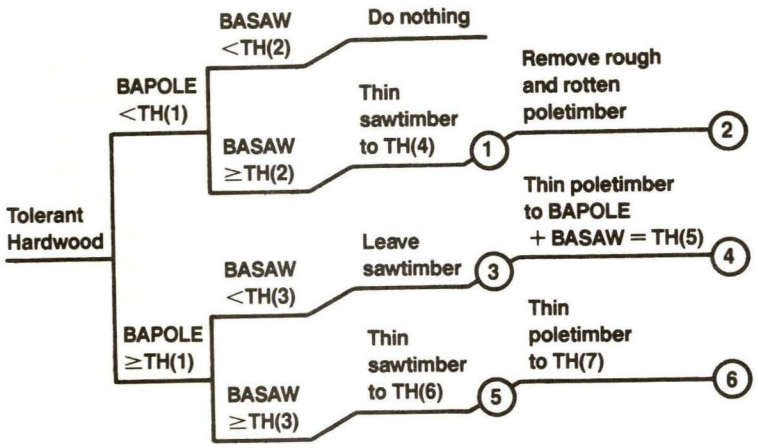
Critical Values

TH(1) = 20. sq. ft./ac
TH(2) = 80. sq. ft./ac
TH(3) = 80. sq. ft./ac
TH(4) = 70. sq. ft./ac
TH(5) = 85. sq. ft./ac
TH(6) = 70. sq. ft./ac
TH(7) = 15. sq. ft./ac
TH(8) = 10. inches

Assumptions

1. Maintain or develop all-aged tolerant hardwood stands.
2. Manage for timber, particularly large products if possible.
3. Minimum sawtimber d.b.h. for BASAW is TH(8).

Figure 4.—*Generalized tolerant hardwood key.*



Critical Values

TH(1) = 20. sq. ft./ac
TH(2) = 90. sq. ft./ac
TH(3) = 80. sq. ft./ac
TH(4) = 60. sq. ft./ac
TH(5) = 75. sq. ft./ac
TH(6) = 80. sq. ft./ac
TH(7) = 15. sq. ft./ac
TH(8) = 10. inches

Assumptions

1. Maintain or develop all-aged tolerant hardwood stands.
2. Manage for timber, particularly large products if possible.
3. Minimum sawtimber d.b.h. for BASAW is TH(8).
4. *Market conditions are poor.*

Figure 5.—*Modified tolerant hardwood key.*

nothing" prescription. In keeping with our new assumption, when treatment is warranted, we may also want to thin more heavily than the guide suggests. If this is the case, we could also lower the values for TH(4), TH(5), and TH(6) so that when, and if, we took any of the three lower branches, the stand would be thinned to a lower residual basal area.

MARKING RULES

Once the decision key determines a prescription, STEMS automatically applies that treatment to the stand. The circled numbers on the right hand side of the decision keys correspond to a set of marking rules that apply the prescription (for example, see figs. 4 or 5). Certain prescriptions are easy to apply and don't need marking rules, as in "do nothing", where all the trees are left to grow, and in "clearcut", where all the trees in the stand are harvested. The "thin" prescription, on the other hand, requires a sequence of priorities assigning which trees to cut first to produce the desired residual stand. This procedure is outlined in a set of marking rules for each decision key (Appendix B). The criteria used to assign trees for cut are tree species, diameter at breast height (d.b.h.), tree quality, and crown ratio.

In the case of tolerant hardwoods, the marking rules are paired so that poletimber and sawtimber classes can be managed separately. Marking rules 1 and 2 specify that the sawtimber size class be thinned and that all rough and rotten poletimber be removed (fig. 6). *Marking rule 1* calls for rough and rotten sawtimber to be removed first (procedure 1), then less desirable species are thinned from above, down to 18 inches d.b.h. (procedure 2). If the basal area limit is not reached before this point, more desirable species will be thinned from above, down to 22 inches d.b.h. (procedure 3). The last two procedures in marking rule 1 thin from the remaining sawtimber-size trees of the undesirable species and then the desirable species, in that order. Cutting stops when the residual basal area prescribed in the decision key is reached. *Marking rule 2* calls for all rough and rotten poletimber-size trees to be removed and is applied regardless of the action taken through marking rule 1. Marking rules 3 through 6 follow similar logic and are found in Appendix B. As with the decision keys, these marking rules can be tailored to fit the user's particular situation by modifying an auxillary data file. Appendix C outlines the method for changing marking rules.

APPLICATIONS

This management component in and of itself has potential for far-reaching applications. Thus far, however, most uses have been made within STEMS.

MARKING RULE 1

Remove rough and rotten sawtimber, thin from above favoring hard maple, other commercial upland hardwoods, walnut, and ash until sawtimber basal area is less than TH(4).

Trees are removed in this order until basal area limit is reached:

Procedure

1. **Remove rough and rotten sawtimber.**
2. **Remove non-hard maple, other commercial upland hardwoods, walnut, ash more than 18 inches d.b.h.**
3. **Remove hard maple, other commercial upland hardwoods, walnut, ash more than 22 inches d.b.h.**
4. **Remove non-hard maple, other commercial upland hardwoods, walnut, ash sawtimber.**
5. **Remove hard maple, other commercial upland hardwoods, walnut, ash sawtimber.**

MARKING RULE 2

Remove all rough and rotten poletimber.

Figure 6.—Tolerant hardwood marking rules 1 and 2.

Managed as well as unmanaged forest inventories have been projected into the future and updated from past to present, and effects of various management strategies have been evaluated. One specific application of management guides within the framework of Lake States STEMS has been the update of statewide forest inventories to provide interim information between major field inventories. In this application, the management guidelines were modified and applied to estimate the total volume of wood that would have been harvested during the update period (Raile and Smith 1982). In another Lake States application, predicted yields were calculated from selected cutting prescriptions using area control constraints, and future deficiencies and surpluses in the forest resource were identified (Jakes and Smith 1980). Management guides have also been used to help assess current treatment opportunities for the forest resource in the North Central States. Forested areas in a State were considered for several classes of silvicultural treatments based on the stand characteristics. Cut volumes generated from simulated silvicultural operations were calculated, and the results represented the volumes that could have been expected if all treatments were carried out (Smith and Jakes 1981).

When using the guides within STEMS, note that there are no built in constraints on the amount of volume or number of acres cut. Actual silvicultural treatments prescribed when projecting the growth of many stands over a large area will probably be applied with some economic or market-related limits in mind. Therefore, when doing regional updates or projections, such as those mentioned earlier, users may have to supplement the management guides with some constraints on acres cut or on the allowable harvest.

These management guidelines can be used outside the framework of STEMS. For example, the guides can be used manually with other growth and yield predictors that do not offer silvicultural guides, such as the TWIGS program, a version of STEMS that operates on mini- and micro-computers (Miner *et al.* In prep.). In contrast to STEMS, TWIGS is ideal for intensive evaluation of one stand at a time. Its management component consists of a menu list of treatment options—but offers no guidelines about which treatment to choose. The management guidelines described in this publication, along with TWIGS and a professional's good judgment, make up a useful set of decisionmaking tools for the natural resource professional.

CONCLUSION

Computerized silvicultural guidelines, based on accepted management practices, have been developed for incorporation into the Central States variant of STEMS. One set of management guidelines for each of six major forest covertypes in the Central States is included in STEMS' management component. Each set of guidelines includes a decision key that prescribes silvicultural treatments and a set of marking rules that implements the prescriptions. The keys use stand and tree characteristics supplied by the user to determine silvicutural prescriptions. Within STEMS the guidelines can automatically be applied to a stand, or they can easily be modified to create a silvicultural prescription that better suits a particular situation. Although these management guides were written to be included in STEMS, they can readily be incorporated into other growth projection

systems or used as a field reference when preparing management prescriptions.

The management guidelines increase the ease, flexibility, and realism of simulating forest management and growth. With this capability, foresters are better able to update past resources and predict future ones, and evaluate the effects of alternative management strategies.

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APPENDIX A

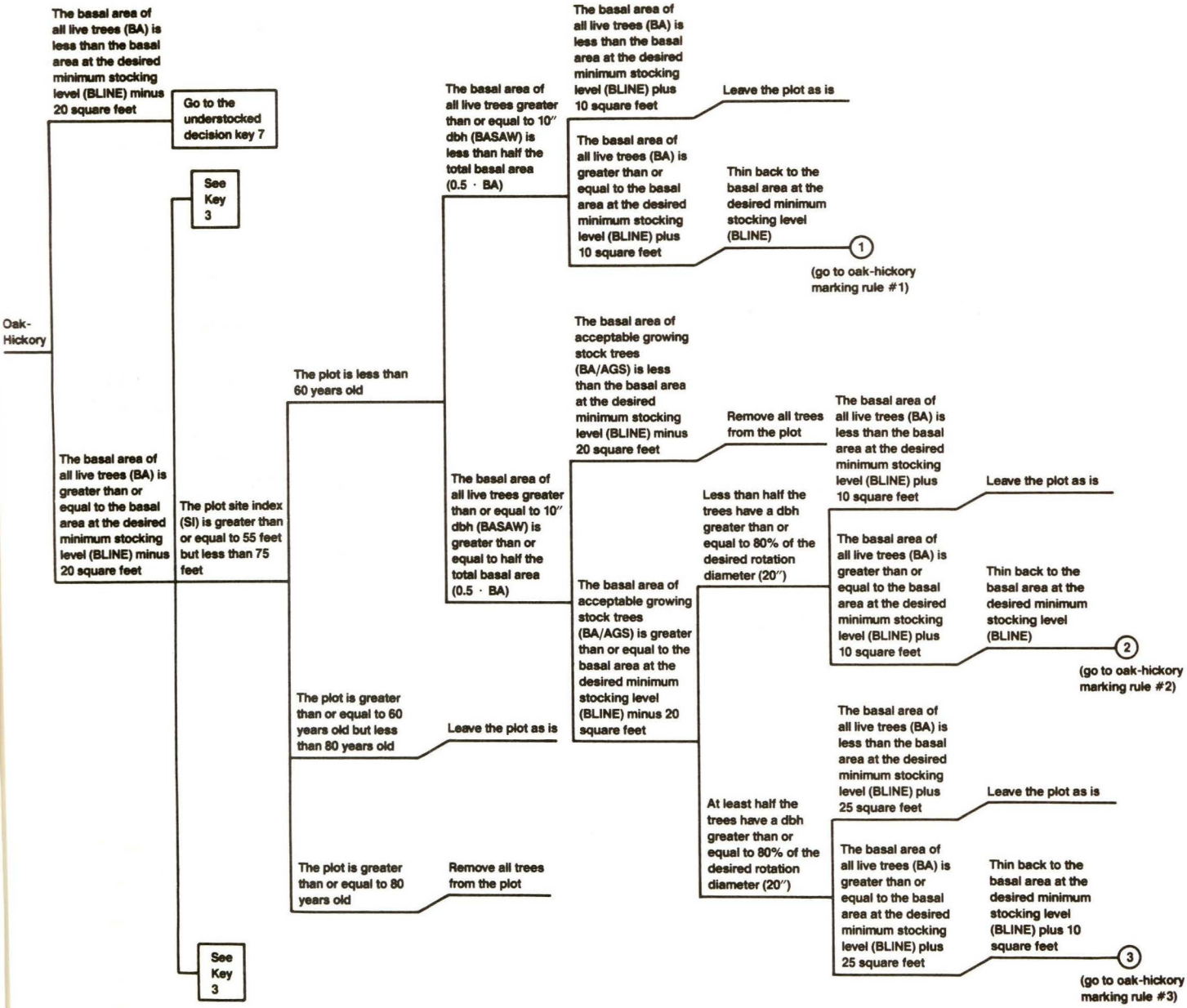
Decision Keys

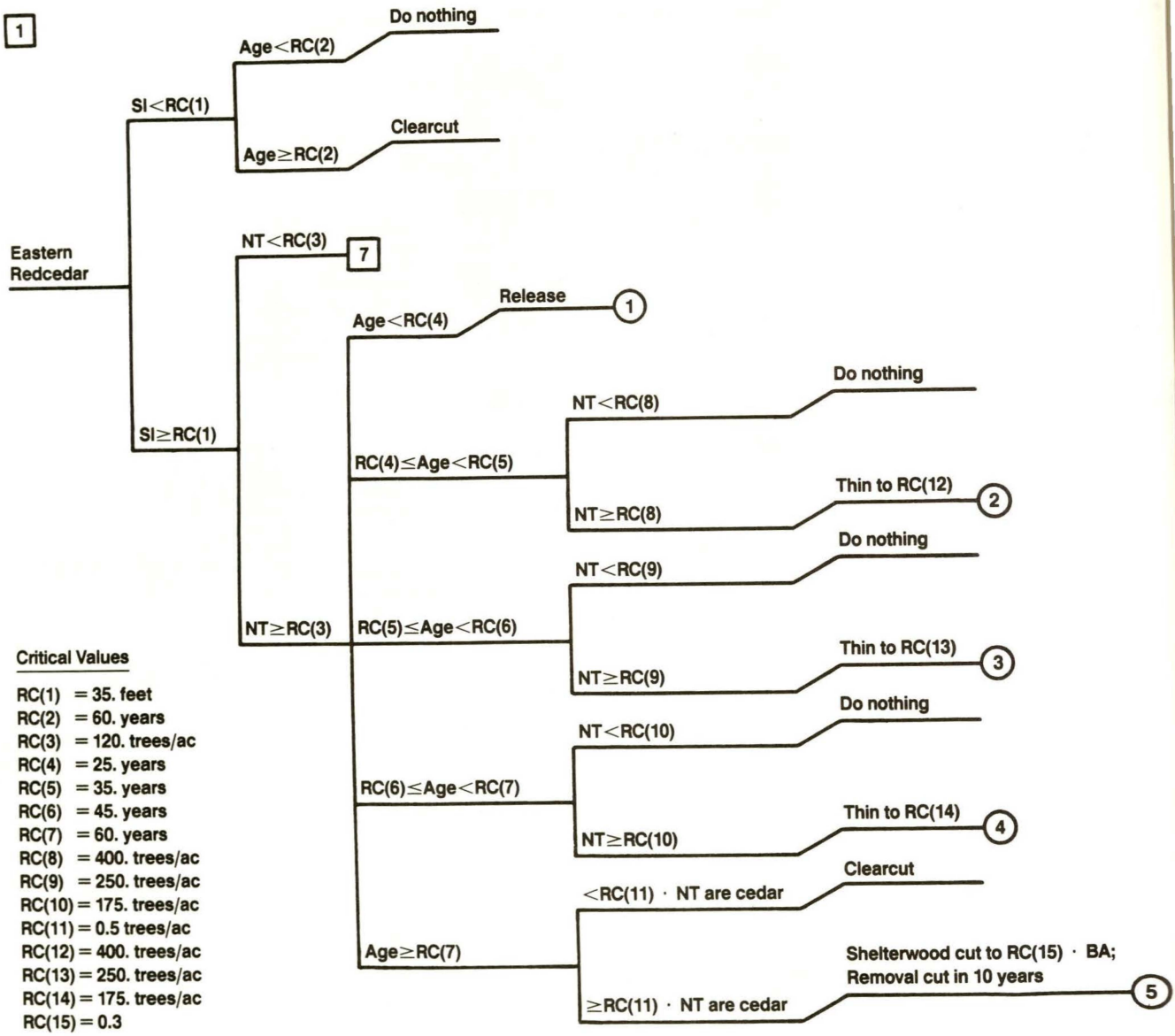
Guide number	Covertype
1	Eastern redcedar
2	Shortleaf pine
3	Central States oak-hickory
4	Elm-ash-cottonwood
5	Pin oak
6	Tolerant hardwood
7	Understocked

Decision key numbers appear within squares. If a key leads to a number within a square, go to the key with that number to determine the management prescription. Numbers that appear within circles indicate the set of marking rules that will be applied. The marking rules are found in Appendix B.

The following key illustrates how to read the center branch of the oak-hickory decision key.

As an example of how to read the decision keys, this page "talks" you through the center branch of the oak-hickory key [3] (see page 12).

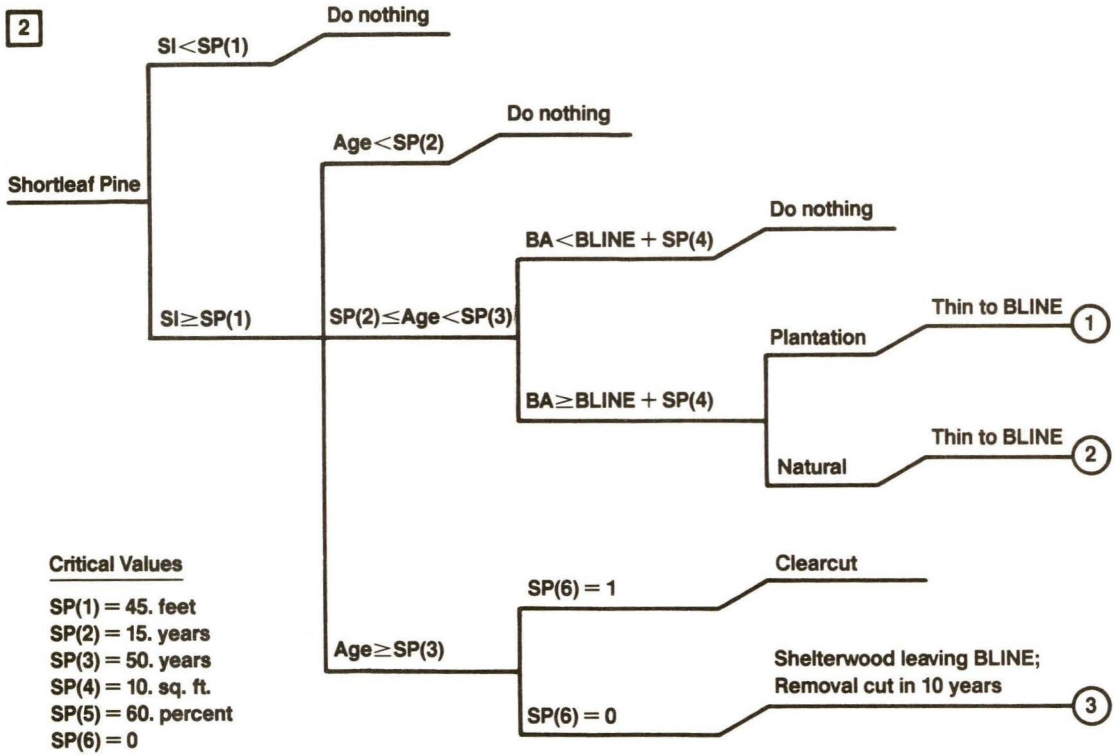

Oak-Hickory
The basal area of all live trees (BA) is less than the basal area at the desired minimum stocking level (BLINE) minus 20 square feet
Go to the understocked decision key 7
The basal area of all live trees (BA) is greater than or equal to the basal area at the desired minimum stocking level (BLINE) minus 20 square feet
See Key 3
The plot site index (SI) is greater than or equal to 55 feet but less than 75 feet
See Key 3
The plot is less than 60 years old
The plot is greater than or equal to 60 years old but less than 80 years old
Leave the plot as is
The plot is greater than or equal to 80 years old
Remove all trees from the plot
The basal area of all live trees greater than or equal to 10″ dbh (BASAW) is less than half the total basal area (0.5 · BA)
The basal area of all live trees (BA) is less than the basal area at the desired minimum stocking level (BLINE) plus 10 square feet
Leave the plot as is
The basal area of all live trees (BA) is greater than or equal to the basal area at the desired minimum stocking level (BLINE) plus 10 square feet
Thin back to the basal area at the desired minimum stocking level (BLINE)
1
(go to oak-hickory marking rule #1)
The basal area of all live trees greater than or equal to 10″ dbh (BASAW) is greater than or equal to half the total basal area (0.5 · BA)
The basal area of acceptable growing stock trees (BA/AGS) is less than the basal area at the desired minimum stocking level (BLINE) minus 20 square feet
Remove all trees from the plot
The basal area of acceptable growing stock trees (BA/AGS) is greater than or equal to the basal area at the desired minimum stocking level (BLINE) minus 20 square feet
Less than half the trees have a dbh greater than or equal to 80% of the desired rotation diameter (20″)
The basal area of all live trees (BA) is less than the basal area at the desired minimum stocking level (BLINE) plus 10 square feet
Leave the plot as is
The basal area of all live trees (BA) is greater than or equal to the basal area at the desired minimum stocking level (BLINE) plus 10 square feet
Thin back to the basal area at the desired minimum stocking level (BLINE)
2
(go to oak-hickory marking rule #2)
At least half the trees have a dbh greater than or equal to 80% of the desired rotation diameter (20″)
The basal area of all live trees (BA) is less than the basal area at the desired minimum stocking level (BLINE) plus 25 square feet
Leave the plot as is
The basal area of all live trees (BA) is greater than or equal to the basal area at the desired minimum stocking level (BLINE) plus 25 square feet
Thin back to the basal area at the desired minimum stocking level (BLINE) plus 10 square feet
3
(go to oak-hickory marking rule #3)



Eastern Redcedar Assumptions

1. Market is such that it is appropriate to manage for eastern redcedar.
2. Management objectives are for saw log production under an even-aged system with rotation age at 60 years.

References: Ferguson *et al.* 1968, Lawson 1985, USDA 1976.



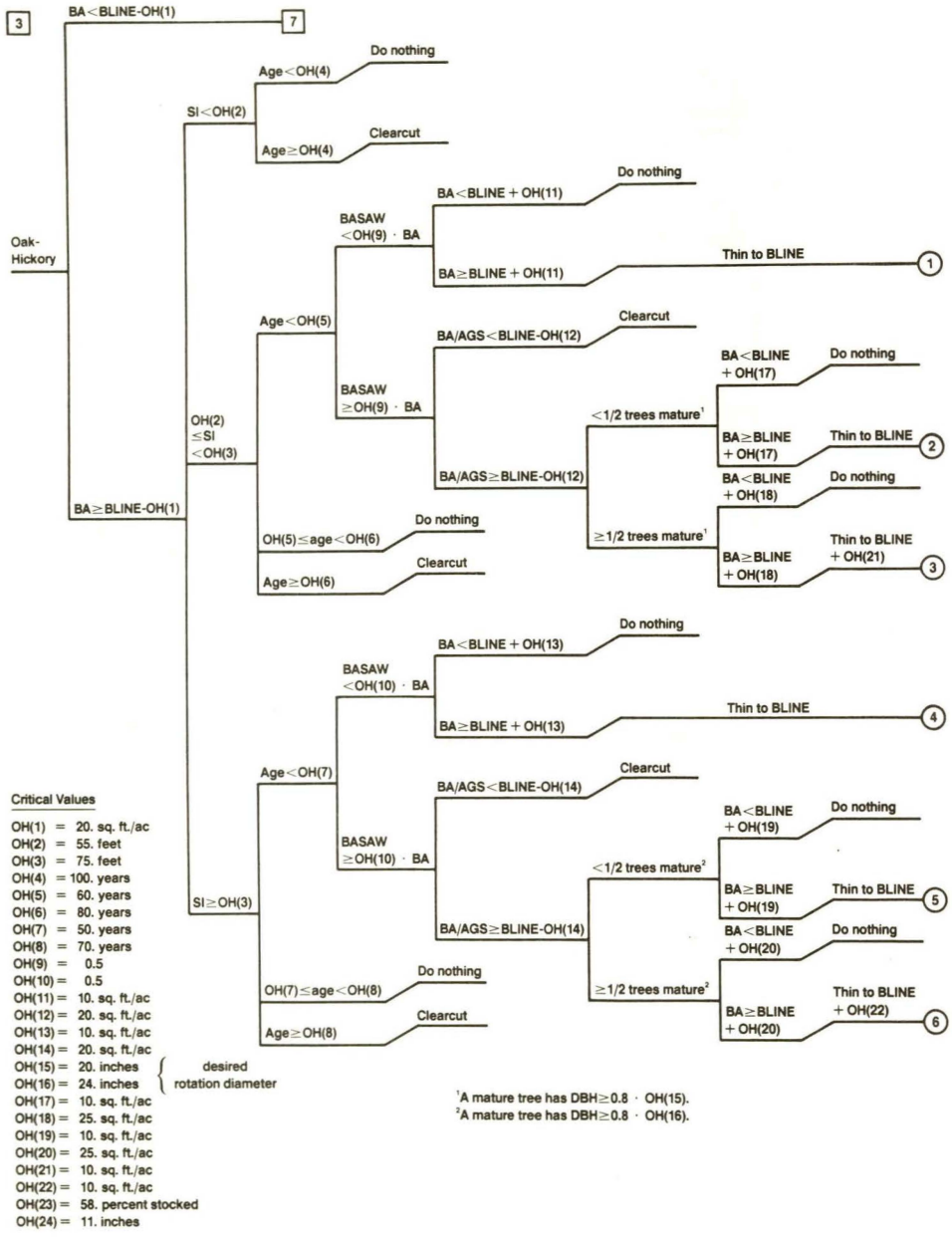
Shortleaf Pine Assumptions

1. Shortleaf pine type consists of sawtimber or poletimber stands in which pine comprises 50 percent or more of the cubic volume, or seedling or sapling stands in which more than half the number of trees are pine.
2. The stand is even-aged.
3. Conditions are appropriate for using the clearcut silvicultural system.
4. The minimum acceptable stand basal area is dependent on the size of the trees present. That is, it is a measure of stocking. The percent of full stocking considered acceptable can be changed by altering SP(5) in the following equation. This equation describes the B-line of the stocking guide in Rogers 1982.

$$\text{BLINE} = \text{SP(5)} \left[(0.05454\ \text{QMDBH}^2)/(0.088 + 0.094\ \overline{\text{DBH}} + 0.025\ \text{QMDBH}^2) \right]$$

5. SP(6) enables the user to determine the harvest method where: 0 = shelterwood cut and 1 = clearcut.

References: Brinkman and Rogers 1967, Brinkman and Smith 1969, Rogers 1982, USDA 1980.

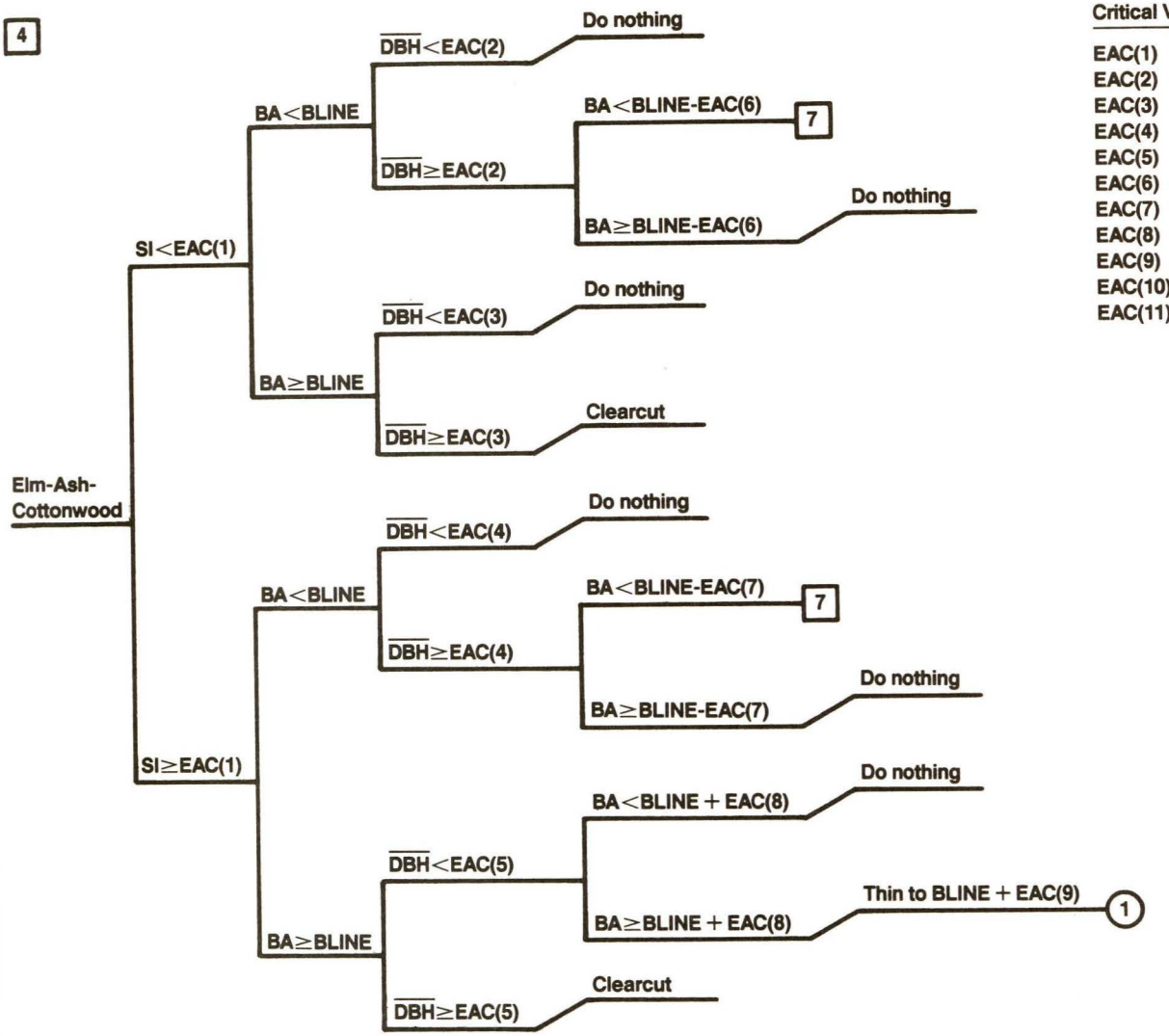


Oak-Hickory Assumptions

1. Management objectives are to favor tolerant hardwoods where the oak site index is high, favor oaks on medium sites, and maintain oaks or convert to another species after clearcutting where the oak site index is low.
2. Manage for timber, particularly large products if possible.
3. Advanced regeneration will be present before clearcutting.
4. Minimum sawtimber DBH for BASAW is OH(24).
5. The minimum acceptable stand basal area is dependent on the size of the trees present. That is, it is a measure of stocking. The percent of full stocking considered acceptable can be changed by altering OH(23) in the following equation. This equation describes the B-line of the stocking guide in Sander 1977.

$$\text{BLINE} = \text{OH}(23)\left[\ (0.05454\ \text{QMDBH}^2)/(-0.0507 + 0.1698\ \overline{\text{DBH}} + 0.0317\ \text{QMDBH}^2)\right]$$

References: Gingrich 1971, Roach and Gingrich 1968, Sander 1977, USDA 1981.



Critical Values

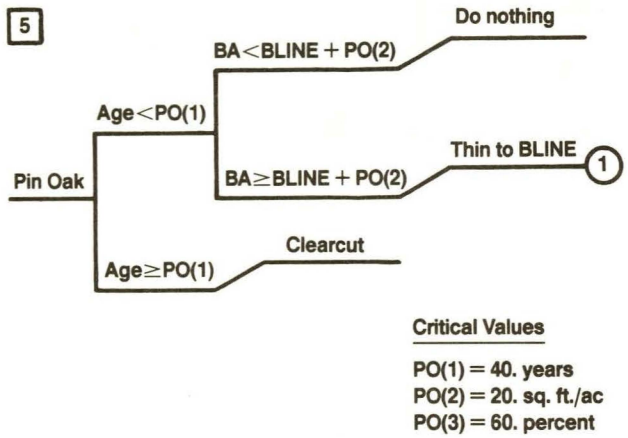
EAC(1)	=	70. feet
EAC(2)	=	5. inches
EAC(3)	=	12. inches
EAC(4)	=	5. inches
EAC(5)	=	24. inches
EAC(6)	=	10. sq. ft./ac
EAC(7)	=	10. sq. ft./ac
EAC(8)	=	20. sq. ft./ac
EAC(9)	=	0. sq. ft./ac
EAC(10)	=	119. sq. ft./ac
EAC(11)	=	0.072

Elm-Ash-Cottonwood Assumptions

1. It is silviculturally appropriate to use even-aged silviculture in the stand.
2. Management objectives can be met using even-aged silviculture.
3. Timber production is the primary objective, particularly large products on good or better sites, pulpwood on poorer sites.
4. Understocked stands can be regenerated to trees.
5. Adequate seed source exists in adjacent stands or the area will be planted after clearcutting.
6. Competing vegetation is controlled in young stands.
7. The minimum acceptable stand basal area is dependent on the size of the trees present. That is, it is a measure of stocking. The percent of full stocking considered acceptable can be changed by altering EAC(10) and EAC(11) in the following equation. This equation describes the B-line of the stocking guide in Myers and Buchman 1984.

$$BLINE = EAC(10)(1\text{-}e^{-EAC(11)\bullet QMDBH})$$

References: Myers and Buchman 1984, Putnam *et al.* 1960, Schlesinger (personal communication).

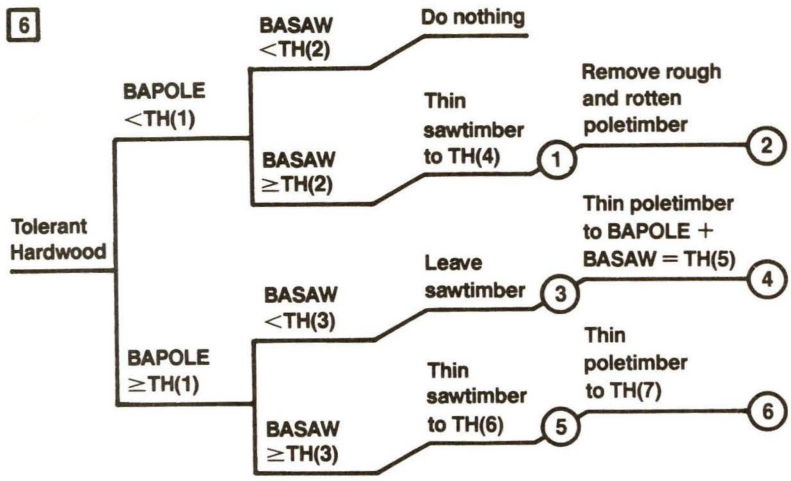


Pin Oak Assumptions

1. A management decision has been made to manage pin oak on a 40-year rotation to produce pilings.
2. The clearcut prescription assumes > 1,500 well spaced desirable hardwood seedlings per acre for advance regeneration.
3. The minimum acceptable stand basal area is dependent on the size of the trees present. That is, it is a measure of stocking. The percent of the full stocking considered acceptable can be changed by altering PO(3) in the following equation. This equation describes the B-line of the stocking guide in Sander 1977.

$$\text{BLINE} = \text{PO(3)} \left[(0.05454 \bullet \text{QMDBH}) / (-0.0507 + 0.1698\ \overline{\text{DBH}} + 0.0317\ \text{QMDBH}^2) \right]$$

References: Putnam 1951, SAF 1981, USDA 1979, 1980.



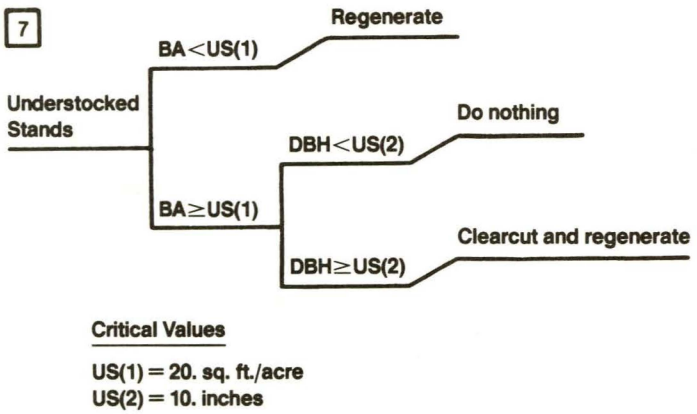
Critical Values

TH(1) = 20. sq. ft./ac
TH(2) = 80. sq. ft./ac
TH(3) = 80. sq. ft./ac
TH(4) = 70. sq. ft./ac
TH(5) = 85. sq. ft./ac
TH(6) = 70. sq. ft./ac
TH(7) = 15. sq. ft./ac
TH(8) = 10. inches

Tolerant Hardwood Assumptions

1. Maintain or develop all-aged tolerant hardwood stands.
2. Manage for timber, particularly large products if possible.
3. Minimum sawtimber d.b.h. for BASAW is TH(8).

References: Tubbs 1977, USDA 1973.



Understocked Stand Assumptions/

1. Stands with a basal area less than 20 square feet are open enough so that they can be regenerated without removing the understory.
2. Stands with a basal area greater than 20 square feet will be operable if the average diameter is greater than 10 inches.

Reference: Brand 1981.

APPENDIX B

Marking Rules

Marking rules consist of a number of removal procedures that carry out the prescription determined by the covertype decision key. The procedures indicate how the cut will be made using tree species, diameter at breast height, crown ratio and quality as criteria. For each covertype, the marking rule numbers refer to the numbers along the right side of the corresponding decision key (Appendix A). For instructions on how to modify these marking rules, see Appendix C.

Eastern Redcedar

Marking Rule 1: Remove all woody competition regardless of position. (BATOT = BA of eastern redcedar).

Procedure: 1. Remove species other than eastern redcedar, taking the smallest diameter trees first.

Marking Rule 2: Remove rough and rotten trees and thin from below, favoring eastern redcedar, until number of trees per acre is less than RC(12).

Procedure: 1. Remove rough and rotten trees.
2. Remove species other than eastern redcedar, taking the smallest diameter trees first.
3. Remove eastern redcedar, taking the smallest diameter trees first.

Marking Rule 3: Remove rough and rotten trees and thin from below, favoring eastern redcedar, until number of trees per acre is less than RC(13).

Procedure: 1. Remove rough and rotten trees.
2. Remove species other than eastern redcedar, taking the smallest diameter trees first.
3. Remove eastern redcedar, taking the smallest diameter trees first.

Marking Rule 4: Remove rough and rotten trees and thin from below, favoring eastern redcedar, until number of trees per acre is less than RC(14).

Procedure: 1. Remove rough and rotten trees.
2. Remove species other than eastern redcedar, taking the smallest diameter trees first.
3. Remove eastern redcedar, taking the smallest diameter trees first.

Marking Rule 5: Make a shelterwood cut, leaving 30 percent of existing basal area in seed cutting (favor eastern redcedar), and make a removal cut 10 years later.

Procedure: 1. Remove rough and rotten trees.
2. Leave largest d.b.h., highest crown ratio, eastern redcedar.

Shortleaf Pine

Marking Rule 1: Manage for pine on a 40-year rotation for posts and poles. Eliminate all non-shortleaf pine, then row thin until basal area is less than the minimum acceptable stocking level (BLINE).

Procedure: 1. Remove species other than shortleaf pine.
2. Remove every third shortleaf pine.

Marking Rule 2: Manage for pine on a 40-year rotation for posts and poles. Thin until basal area is less than BLINE, eliminating inferior and competing hardwoods.

Procedure: 1. Remove rough and rotten trees.
2. Remove species other than shortleaf and loblolly pine, taking the smallest diameter trees first.
3. Remove shortleaf and loblolly pine, taking the smallest diameter trees first.

Marking Rule 3: Make a shelterwood cut leaving the minimum acceptable stocking level (BLINE) in the seed cutting, favoring shortleaf pine. Make a removal cut 10 years later.

Procedure: 1. Remove rough and rotten trees.
2. Leave largest d.b.h., highest crown ratio shortleaf pine.

Central States Oak-Hickory

Marking Rules 1, 2, and 3: Remove rough and rotten trees and thin from below, discriminating against undesirable species and favoring shortleaf pine and valuable oaks.

Procedure: 1. Remove rough and rotten trees.
2. Remove tupelo, beech, elm, and noncommercial species, taking the smallest diameter trees first.
3. Remove soft maple, hard maple, other upland hardwoods, and other lowland species, taking the smallest diameter trees first.
4. Remove species other than red oak, black oak, white oak, and shortleaf pine, taking the smallest diameter trees first.

5. Remove red oak, black oak, white oak, and shortleaf pine, taking the smallest diameter trees first.

Marking Rules 4, 5, and 6: Remove rough and rotten trees and thin from below, discriminating against undesirable species and favoring valuable oaks, black walnut, and white ash.

Procedure:
1. Remove rough and rotten trees.
2. Remove tupelo, beech, elm and non-commercial species, taking the smallest diameter trees first.
3. Remove soft maple, hard maple, other upland hardwoods, and other lowland species, taking the smallest diameter trees first.
4. Remove species other than red oak, black oak, black walnut, and white ash, taking the smallest diameter trees first.
5. Remove red oak, black oak, black walnut, and white ash, taking the smallest diameter trees first.

Elm-Ash-Cottonwood

Marking Rule 1: Remove rough and rotten trees and thin from below, favoring green ash, silver maple, cottonwood, and sycamore, until basal area is less than the minimum acceptable stocking level (BLINE).

Procedure:
1. Remove rough and rotten trees.
2. Remove species other than green ash, silver maple, cottonwood, black walnut, and sycamore, taking the smallest diameter trees first.
3. Remove green ash, silver maple, cottonwood, black walnut, and sycamore, taking the smallest diameter trees first.

Tolerant Hardwoods

Marking Rules 1 and 2: Remove rough and rotten sawtimber; thin, favoring hard maple, other commercial upland hardwoods, walnut, and ash until sawtimber basal area is less than TH(4); and remove all rough and rotten poles.

Sawtimber procedure:
1. Remove rough and rotten sawtimber.
2. Remove species other than hard maple, other commercial upland hardwoods, walnut, and ash more than 18 inches d.b.h., taking the largest diameter trees first.
3. Remove hard maple, other commercial upland hardwoods, walnut, and ash more than 22 inches d.b.h., taking the largest diameter trees first.
4. Remove species other than hard maple, other commercial upland hardwoods, walnut, and ash sawtimber, taking the smallest diameter trees first.
5. Remove hard maple, other commercial upland hardwoods, walnut, and ash sawtimber, taking the smallest diameter trees first.

Poletimber procedure:
1. Remove rough and rotten poletimber.

Marking Rules 3 and 4: Leave sawtimber; remove rough and rotten poletimber; and thin poletimber from below, favoring hard maple, other commercial upland hardwoods, walnut, and ash until poletimber and sawtimber basal area combined is less than TH(5).

Sawtimber procedure:
1. Do nothing to the sawtimber.

Poletimber procedure:
1. Remove rough and rotten poletimber.
2. Remove species other than hard maple, other commercial upland hardwoods, walnut, and ash poletimber, taking the smallest diameter trees first.
3. Remove hard maple, other commercial upland hardwoods, walnut, and ash poletimber, taking the smallest diameter trees first.

Marking Rules 5 and 6: Remove rough and rotten sawtimber and poletimber; thin sawtimber, favoring immature hard maple, other commercial upland hardwoods, walnut, and ash until sawtimber basal area is less than TH(6); and thin poletimber from

below, favoring hard maple, other commercial upland hardwoods, walnut, and ash until poletimber basal area is less than TH(7).

Sawtimber procedure:
1. Remove rough and rotten sawtimber.
2. Remove species other than hard maple, other commercial upland hardwoods, walnut, and ash more than 18 inches d.b.h., taking the largest diameter trees first.
3. Remove hard maple, other commercial upland hardwoods, walnut, and ash more than 22 inches d.b.h., taking the largest diameter trees first.
4. Remove species other than hard maple, other commercial upland hardwoods, walnut, and ash sawtimber, taking the smallest diameter trees first.
5. Remove hard maple, other commercial upland hardwoods, walnut, and ash sawtimber, taking the smallest diameter trees first.

Poletimber procedure:
1. Remove rough and rotten poletimber.
2. Remove species other than hard maple, other commercial upland hardwoods, walnut, and ash poletimber, taking the smallest diameter trees first.
3. Remove hard maple, other commercial upland hardwoods, walnut, and ash poletimber, taking the smallest diameter trees first.

APPENDIX C

Modifying the Marking Rules

Appendices A and B outline the prescriptions and marking rules that are systematically applied to stands projected by STEMS. As mentioned, STEMS users can modify both the marking rules and the prescription to fit their particular situations. Appendix C explains how to modify the marking rules; a discussion of how to modify the prescription is found in the text.

As seen in Appendix B, each covertype marking rule consists of a number of removal procedures. The procedures use tree species, diameter, crown ratio, and quality to indicate how the cut will be made. This information is stored in a series of codes in an auxiliary data file. Each procedure is characterized using a field of 13 digits; the first number indicates how the cut will be made (procedure codes in table 2) and the following numbers supply the specific information needed to carry out the cut. *The user can modify the removal procedures by changing the codes in the auxiliary file before making a STEMS run.*

The following example demonstrates how the codes are used.

Marking rule 1 in the tolerant hardwood guide outlines a thin with the following procedures:

1. First, remove rough and rotten sawtimber of any species;
2. next, remove undesirable species from above (cut largest diameter trees first) down to 18 inches d.b.h.;
3. then, remove desired species from above down to 22 inches d.b.h.;
4. continue by removing the remaining undesirable sawtimber (starting with the smallest diameter trees);
5. and finally, remove desired species of sawtimber size, removing smallest diameter trees first.

The codes that produce this marking rule are:

	Procedure code	Lower diameter limit	Upper diameter limit	Species group code*	Species group code*	Species group code*	Species group code
Position	1	2 3	4 5	6 7	8 9	10 11	12 13
	1	1 0	9 9	0 0	0 0	0 0	0 0
	3	1 8	9 9	1 8	1 9	0 6	0 0
	5	2 2	9 9	1 8	1 9	0 6	0 0
	2	1 0	9 9	1 8	1 9	0 6	0 0
	4	1 0	9 9	1 8	1 9	0 6	0 0

**species group code 18 is hard maple, 19 is ash, and 6 is walnut. (See table 3 for a complete list of Central States species group codes.)*

Up to five removal procedures can be combined to simulate a marking rule. Using the nine procedure options and the criteria for cuts, many different marking rules can be created.

Table 2.—*Removal procedures*

Procedure CODE	Procedure	Information needed for coding	Digit position	Code/Value
1	Remove rough and rotten trees in designated size class until required BA is achieved. (Tree quality codes are needed for this procedure).	Size class to remove	1 2-3 4-5 6-13	1 Lower diameter limit Upper diameter limit All zeros
2	Remove smallest trees of unspecified species until required BA is achieved.	Size class to remove, 4 species groups to leave.	1 2-3 4-5 6-7, 8-9 10-11, 12-13	2 Lower diameter limit Upper diameter limit 4 species group codes to leave
3	Remove largest trees of unspecified species until required BA is achieved.	Size class to remove, 4 species groups to leave.	1 2-13	3 Same as 2
4	Remove smallest trees of specified species until required BA is achieved.	Size class to remove, 4 species groups to remove.	1 2-3 4-5 6-7, 8-9 10-11, 12-13	4 Lower diameter limit Upper diameter limit 4 species group codes to remove
5	Remove largest trees of specified species until required BA is achieved.	Size class to remove, 4 species groups to remove.	1 2-13	5 Same as 4
6	Shelterwood cut leaving required BA (leave largest d.b.h., highest crown ratio trees).	Size class to remove, 4 species groups to favor.	1 2-3 4-5 6-7, 8-9 10-11, 12-13	6 Lower diameter limit Upper diameter limit 4 species group codes to favor
7	Reduce number of trees.	Number of trees to leave.	1 2-5 6-13	7 Number of trees/acre to leave All zeros
8	Remove all overtopping.	Lower d.b.h. of trees to remove.	1 2-3 4-13	8 Lower d.b.h. of trees to remove All zeros
9	Remove all trees of a certain size and species.	Size class to remove, 4 species groups to remove.	1 2-13	9 Same as 4

Table 3.—*Central States STEMS species codes*

Group code	Species code	Species
1	068	Eastern redcedar
	060	Juniper
2	110	Shortleaf pine
3	132	Virginia pine
	131	Loblolly pine
4		Other softwoods
	129	White pine
5		—
6		Walnut
	602	Black walnut
	601	Butternut
7		Tupelo
	694	Swamp tupelo (blackgum)
	691	Water tupelo
	693	Black tupelo
8		Select hickory
	407	Shagbark hickory
	405	Shellbark hickory
	409	Mockernut hickory
9		Other hickory
	403	Pignut hickory
	400	Hickory spp.
	401	Water hickory
	402	Bitternut hickory
	404	Pecan
	408	Black hickory
10		Beech
	531	American beech
11	543	Black ash
	545	Pumpkin ash
	546	Blue ash
12	742	Cottonwood
13		Soft maple
	316	Red maple
	313	Boxelder
	317	Silver maple
14		Cherry
	762	Black cherry
15		Elm
	972	American elm
	461	Sugarberry
	462	Hackberry
	971	Winged elm
	970	Elm spp.
	974	Siberian elm
	975	Red elm
	977	Rock elm
16	621	Yellow poplar

(Table continued)

Table 3.—*Central States STEMS species codes* (Continued)

Group code	Species code	Species
17		Basswood
	951	American basswood
18		Hard maple
	318	Sugar maple
19		White and green ash
	541	White ash
	540	Ash spp.
	544	Green ash
20	802	White oak
21		Red oak
	833	Northern red oak
	812	Southern red oak
22	837	Black oak
23	806	Scarlet oak
24	824	Blackjack oak
25	826	Chinkapin oak
	804	Swamp white oak
	823	Bur oak
	825	Swamp chestnut oak
26	835	Post oak
	836	Delta post oak
27	832	Chestnut oak
28	830	Pin oak
	809	Northern pin oak
	813	Cherrybark oak
	817	Shingle oak
	822	Overcup oak
	827	Water oak
	828	Nuttall oak
	831	Willow oak
	834	Shumard oak
29		Other upland hardwoods
	931	Sassafras
	331	Ohio buckeye
	452	Catalpa
	521	Persimmon
	550	Honey locust spp.
	552	Honey locust
	741	Balsam poplar
	743	Bigtooth aspen
	746	Quaking aspen
	901	Black locust
30		Other lowland species
	731	Sycamore
	221	Baldcypress
	373	River birch
	611	Sweetgum
	920	Willow spp.
	922	Black willow

(Table continued)

Table 3.—*Central States STEMS species codes (Continued)*

Group code	Species code	Species
31		Noncommercial species
	999	Misc. noncommercial
	391	Blue beech
	471	Redbud
	491	Dogwood spp.
	500	Hawthorn spp.
	571	Kentucky coffeetree
	641	Osage orange
	651	Cucumber tree
	653	Sweetbay
	680	Mulberry
	681	White mulberry
	682	Red mulberry
	701	Ironwood
	711	Sourwood

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